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13. ABSTRACT (Maximum 200 words) The water immersion laboratory (WIL) simulates cold and hot environments by changing the water temperature in a concrete vessel through a steam-driven heat exchanger and ethylene glycol-jacketed chiller. The desired temperature is precisely manipulated and controlled by pneumatic control valves, which receive signals from transducers, and display temperature outputs for each sensor on the digital indicators at the control panel. The temperature is changed to desired protocol conditions for evaluation of human responses to cold or heat stress. The control system and supporting equipment are designed for sustained periods of operation.				
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**WATER IMMERSION AND RE-WARMING FACILITY
OF THE
THERMAL AND MOUNTAIN MEDICINE DIVISION**



AN INFORMATION BOOKLET

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US Army Medical Research and Development Command

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WATER IMMERSION LABORATORY

MISSION STATEMENT

To sustain and enhance exercise capabilities and tolerance, and minimize medical problems associated with military operations at environmental extremes of heat, cold and terrestrial altitude.

THEORY OF OPERATION AND FACILITY ENGINEERING

The water immersion laboratory (WIL) simulates cold and hot environments by changing the water temperature in a concrete vessel through a steam-driven heat exchanger and ethylene glycol-jacketed chiller. The desired temperature is precisely manipulated and controlled by pneumatic control valves, which receive signals from transducers, and display temperature outputs for each sensor on the digital indicators at the control panel. The temperature is changed to desired protocol conditions for evaluation of human responses to cold or heat stress. The control system and supporting equipment are designed for sustained periods of operation.

DESIGN FEATURES

The WIL is a unique facility due to its water depth and capability to allow exercise in two different modes: cycle ergometry and treadmill walking. The two cycle ergometers and the treadmill are situated on separate platforms, independently operated and controlled, and immersed in water set to the desired temperature for each protocol scenario. Two cycle ergometers are operated from a pair of fixed stainless steel chairs. Each ergometer has a

moveable plate system to allow adjustments for individual leg length. The ergometer platform is lowered into the water by a ½ ton DeMag chain hoist, electrically isolated and ground fault interrupter (GFI)-maintained circuit for human volunteer protection. The second platform has a hydraulically operated underwater treadmill (Model AquaGaiter™) and is lowered by a ½ ton Coffing chain hoist also on an electrically isolated circuit with remote control operations. (Color photos of the cold/heat immersion pool from two views are shown in Figure 1.) The WIL incorporates a self-contained re-warming facility following cold-water experiments. (A color photo of the device is shown in Figure 2. The design layout and physical specifications are shown in Figure 3.)

The main pool dimensions are 3.08 m (10 ft) length by 3.08 m (10 ft) width by 4.31 m (14 ft) depth, and its capacity is 37,800 liters (10,000 gals) of water. The operational range of the temperature controller for the pool is 5°- 50°C (41° - 122 °F). The majority of human exposures in test protocols range from 15° - 40°C (59 ° -104 °F).

The re-warming pool dimensions are 154.9 cm (61") long by 114.3 cm (45") wide by 63.5 cm (25") deep, and its capacity is ~2000 liters (530 gals) of water. The normal operational temperature range for the re-warming pool is 36°- 40°C (97°- 104°F).

TEMPERATURE CONTROL SYSTEM

The temperature control logics system is a Network 8000 Model (88210) Controller with analog –to- digital LAN wiring. The system incorporates Global Control modules and Local Control modules interfaced

with mechanical and electrical equipment to provide temperature control of the pool.

Independent heating and cooling control units consisting of a steam-jacketed heat exchanger and a water/glycol chiller support the WIL. The temperature control system has chilled/hot water control valves to allow a bias flow (controlled circuit loops) of tempered water to achieve desired temperature with minimal over-compensation. The specifications allow for a cooling rate of $\text{minus } 3.5^{\circ} \pm 0.5^{\circ}\text{C}$ per hour at moderate temperature ranges (24° - 31°C). The heating capacity allows for a heating rate of $\sim 7^{\circ}\text{C}$ per hour over a temperature range of 20° - 45°C .

PERFORMANCE TESTING RESULTS AND DISCUSSION

The precision around the temperature setting is critical to our research applications of the WIL. The evaluation consisted of setting a desired temperature and measuring the pool temperature with an Omega precision RTD bench top thermometer calibrated to a medical standard by the manufacturer and verified by the Army Test Measurement & Diagnostic Evaluation or instrument calibration department. The results from repeated measures over several weeks produced a standard curve for the WIL. The brass standard for our evaluation is the Omega thermometer and was validated from two separate and different sources. The Network 8000 temperature thermistors (NT8000T) were installed and calibrated by company engineering personnel prior to test evaluations. The results over the range of temperatures for both devices were linear and the best area of agreement was at $15^{\circ} \pm 0.2^{\circ}\text{C}$. The NT8000T underestimated pool temperature at in as range of temperatures from $20^{\circ} - 35^{\circ} \pm 0.5^{\circ}\text{C}$.

Furthermore, the NT8000T underestimated pool temperatures in a range from $35^{\circ} - 50^{\circ} \pm 1.0^{\circ}\text{C}$. The precision of the NT8000T ranged from ± 0.2 to $\pm 1.0^{\circ}\text{C}$ over the entire range from 10° to 50°C for the WIL.

CONCLUSIONS

The WIL is capable of providing cold and heat exposure protocols for human volunteers via the water immersion pool. The facility has both cycle ergometry and treadmill exercise capabilities. The facility has a re-warming component for control of hypothermia in humans exposed to cold stress. The WIL provides dedicated, continuous, pool temperature monitoring for a wide range of environmental temperatures.

- Figure 1. The water immersion facility with exercise equipment and support platforms.
- Figure 2. Emergency re-warming pool for relief from acute hypothermia.
- Figure 3. Engineering schematic of water immersion laboratory.

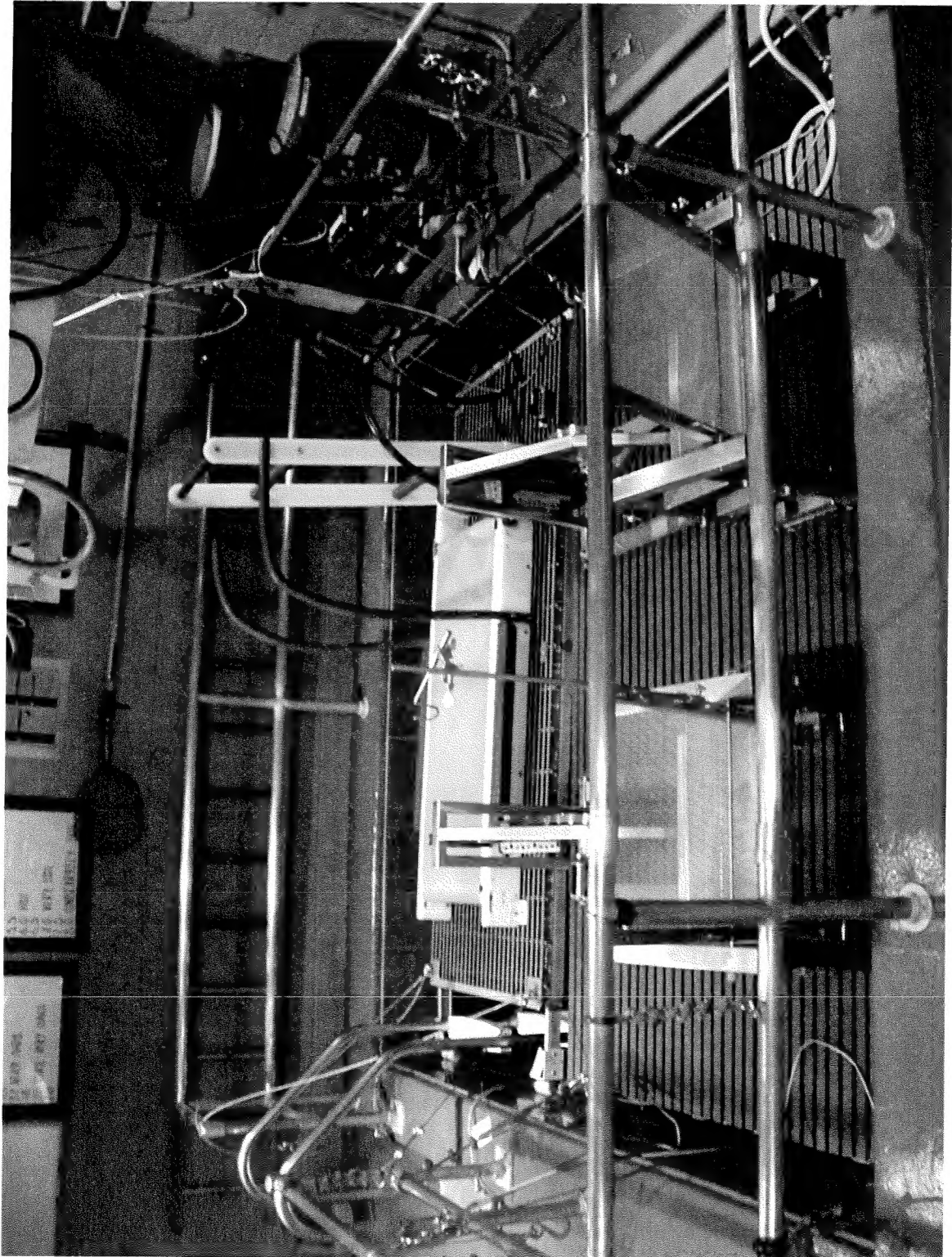
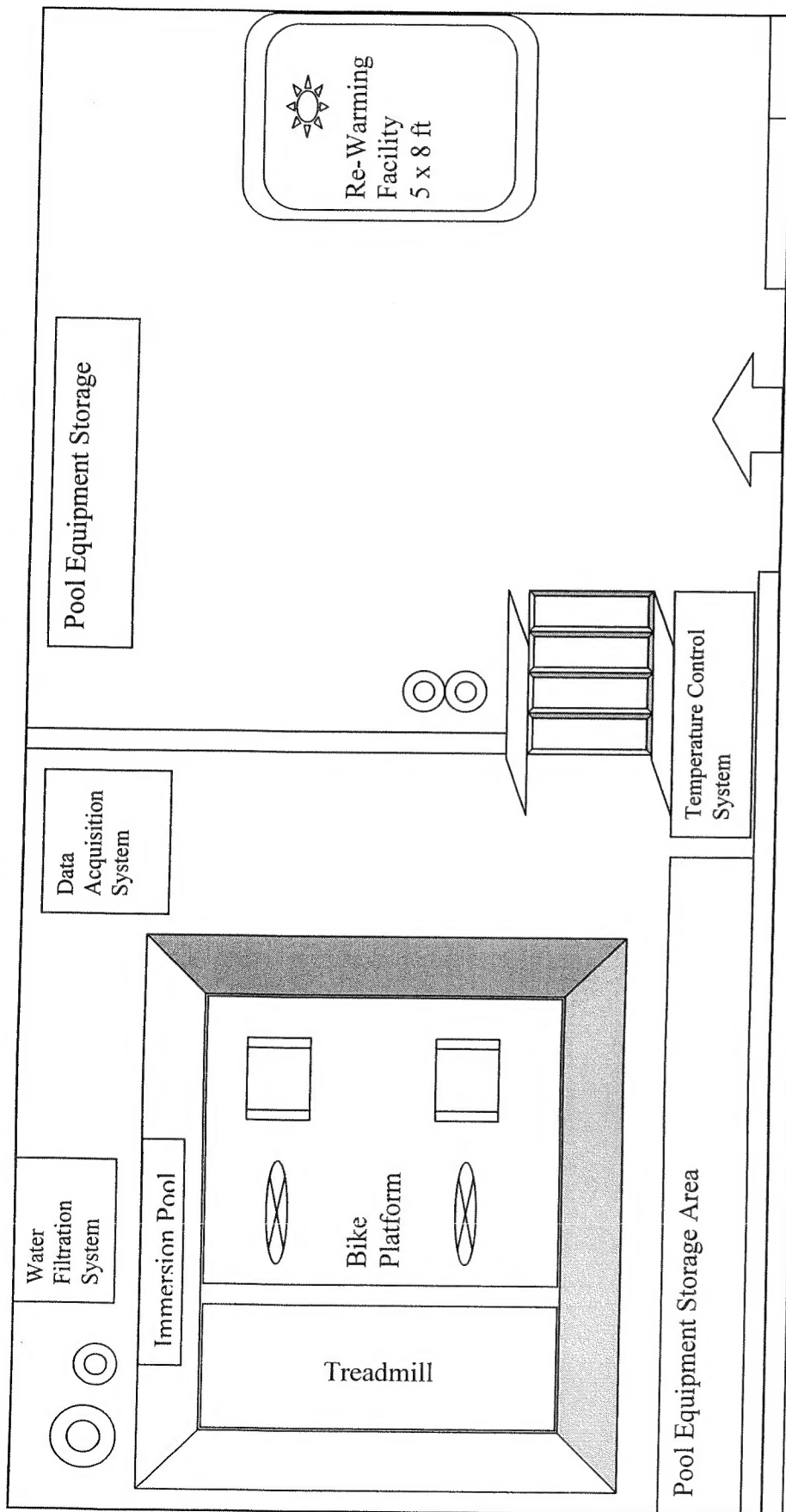


Figure 1. Water immersion facility with exercise equipment and support platforms.



Figure 2. Emergency re-warming pool for relief from acute hypothermia.



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OPERATIONAL SPECIFICATIONS

TEMPERATURE RANGE: High 50°C (122°F) to Low 5°C (41°F) by steam-driven heat exchanger and ethylene glycol-jacketed chiller.

POOL DIMENSIONS: 3.08 m (10 ft) long x 3.08 m (10 ft) wide x 4.31 m (14 ft) deep.

CAPACITY: 37,800 L (10,000 gals) of water.

EXERCISE FACILITIES: Two cycle ergometers (adjustable for leg length) and one variable speed submersible treadmill (adjustable to 6 depths).
HOIST: 2 - ½ ton chain drive systems.

TEMPERATURE CONTROL SYSTEM: Network 8000 Model (88210) controller with analog to digital LAN wiring

VARIABILITY: Cooling rate of minus 3.5° ± 0.5°C per hour. Heating rate of ~7°C per hour.

Figure 3. An Illustration of the immersion and re-warming facility with physical and operational specifications.



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